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ECONOMICAL EVALUATION OF THE CARBONATION-CALCINATION SYSTEM FOR CAPTURING CO2

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Abstract

The cost of the CO_2 capture using carbonation-calcination cycles as a technological option of the CO_2 capture in post combustion is the sum of several terms: sorbent costs, capital costs related to the capture plant, the new operation and maintenance processes, the cost of the additional fuels necessary to compensate the penalty in the efficiency due to the capture, and the cost of the CO_2 compression.

The required conditions for the sorbents are that they have to be either very goods or very cheap. The cost of the sorbent flow can't be higher than 1-3 € per separated CO_2 ton. In the case of utilisation of $CaCO_3$ as a sorbent, it has been calculated that the cost per separated CO_2 ton is 2,5 €. The problem of this sorbent is that its deactivation is quick, but this is compensated by its high abundance in the nature.
Apart from this, it has to be into account other terms in order to obtain the global cost. It has supposed a generation plant of 360 MW with a fluidized bed reactor. It has been estimated that it can be reached a realistic capture up to 78% in the carbonator using

CaO as a sorbent, as well as a 100% of the CO_2 generated in the calcinator, resulting capture rates of 85% approximately.

The assumptions for the operation and maintenance are that the carbonators require a molar relation Ca/C of 4 for an effective CO_2 capture, a 30% of the fuel is burned in the calcinators and the rest in the combustor, the capacity of the CaO to capture CO_2 decreases with the number of cycles, the recuperation rate of CaO is 92,5%, the global efficiency of the plant is 40,7%, the fuel is petroleum coke or anthracite.
Furthermore, taking also into account the capital costs and the compression of the CO_2, it has been calculated that the global cost is 15,5 € for a life of 30 years of the plant.

Therefore, a priori it seems to be a reasonable cost compared with the technological options of CO_2 capture that are in operation nowadays, specially those which use amines.

Introduction

The CO_2 capture represents nowadays one of the most important options that are planned in order to decrease the emissions of this gas related to the combustion of the fossil fuels and to fight in this way the climate change

One of the existent solutions for capturing CO_2 is through the carbonation-calcination cycles, which is one of the technological options of CO_2 capture in post combustion, that consists in the CO_2 separation at a high temperature.

For this technology would be successful, it must be demonstrated its viability either technical or economical at an industrial scale. This last aspect is essential, and is for that reason that it has been realized a detailed economical analysis of this process.

Economical Analysis

Making the economical analysis, it has been taken into account all the factors that determine the final price of CO_2 capture by means of this technology.

The cost of the CO_2 capture is the addition of several terms, where are included the sorbent costs, the elevated capital costs related to the capture plant, the new operation and maintenance costs, the cost of the additional fuels necessary to compensate the penalty in the efficiency due to the capture, and the CO_2 compression cost.

Firstly, an analysis about the sorbent costs has been realized. The CO_2 capture systems are relevant due to the elevated sorbent quantities that are used, at least high enoughly to equalize the CO_2 molar flow that is processed in the plant.

In our case, we have the limestone as sorbent ($CaCO_3$), which has been compared with the systems based on amines (MEA), because they are the most used up to now in the industry. The requested condition to the sorbents is either very goods or very cheaps.

A low comparative cost in the composition of the sorbent per CO_2 unit separated, will be essential for any sorption-desorption system for capturing CO_2. We can define the sorbent cost per CO_2 kg separated (COS) according to the following equation:

$$COS = \left(\frac{F_0}{F_R}\right)\left(\frac{F_R}{F_{CO_2}}\right)\frac{bM_s}{M_{CO_2}}C_s = \left(\frac{F_0}{F_R}\right)\frac{C_s^*}{M_{CO_2}}$$, where:

- COS : cost of sorbent makeup per tonne of CO2 removed (€/kg of CO_2)
- F_0 : makeup flow of sorbent (mol/s)
- F_R : flow of sorbent required to react with the flow of CO_2 (mol/s)
- F_{CO_2} : flow of CO_2 removed by the capture system (mol/s)
- b : moles of sorbent required to stoichiometrically react with 1 mol of CO_2 (or O_2)
- M_s : molecular weight of the sorbent (kg/mol)
- M_{CO_2} : 0,044 kg/mol
- C_s : unit cost of sorbent (€/kg)

The term $C_s^* = M_s\, C_s\, b\, \left(F_R / F_{CO_2}\right)$ is a suitable variable to compare the cost of the different sorbents, because it represents the cost of the quantity of sorbent required to react (or absorb) with 1 mol of CO_2 (or O_2).
For a typical system selected as a reference and base don MEA, b = 2, M_{MEA} = 0,061 , C_S = 1,35 €/kg MEA, and the flow of the fresh sorbent is 1,5 kg of MEA per CO_2 tonne. The other terms correspond to values of F_0/F_R = 0,000152 and F_R/Fco_2 = 3,57. Therefore, the term C_s^* = 0,589 €/mol of CO_2 and a sorbent composition cost for systems at high scale based on MEA of approximately COS_{MEA} = 0,00203 €/kg CO_2, ro 2,03 € / CO_2 captured tonne.

The logical basis that resides in the economical analysis is that the performance of the sorbent in any new system of CO_2 capture would be of an enough quality that assure that the fresh sorbent costs would be comparable with those that are being reached nowadays for a commercial technology already tested, for example, absorption with MEA. This is assumed to be a necessary condition (but not enough), because it is considered improbable that other benefits which come from a new and not tested technology could compensate the costs of the CO_2 capture process. However, one condition could be benefit for the introduction of such improvements, and this is that the emission of the CO_2 to the atmosphere was more expensive than its own capture.
For the regenerative sorbents, the energetic requeriments represent the main contribution in the global capture costs.

The natural limestones have been studied as regenerable sorbents for the CO_2 separation. Nevertheless, the sorbent cannot maintain a high capacity capture further than 20 cycles, and are required high quantities of limestone for the CO_2 control. This only can be accepted because the low price of the limestone and because the calcinated products could acquire a value for the cement industry.

If we analyze the necessary sorbent for the CO2 capture by means of the carbonation-calcination process, the CaCO3, the obtained calculations are the following.

As according to the previous equations, we have:

COS_{CaCO_3} = 0,00251 € / kg CO_2 = 2,51 € / CO_2 capture tonne

However, these new sorbents have to be tested in order to check the reactivity and capture capacity in a higher number of cycles.

Taking into account the rest of the factors that influence in the global CO2 capture cost, and making for that some assumptions, it has been estimated an approximated cost of 15,5 €.

Conclusions

The sorbent cost of the $CaCO_3$ is very cheap, carrying out at least one of the premises of how the sorbents have to be, what provokes that the big advantage of this sorbent lies in the large existent abundance of limestione. Nevertheless, the big inconvenient is that its deactivation is very quick.

This shows that the sorbents based on calcium have the potential of being economically competitive with other present capture technologies. More studies and tests have needed to improve the information about the performance of the sorbents and the equipment costs, and to give a more detailed comparation between this process and other technological alternatives.

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